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Single-frequency semiconductor lasers
Gallium arsenide ICs • Con Ed's fuel-cell power plant
HDTV: problems and promises • The engineer's environment II
Mervin J. Kelly: manager and motivator

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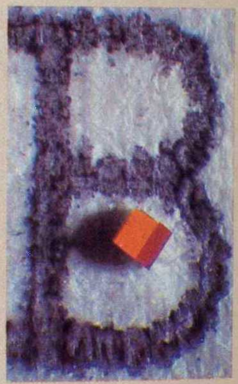
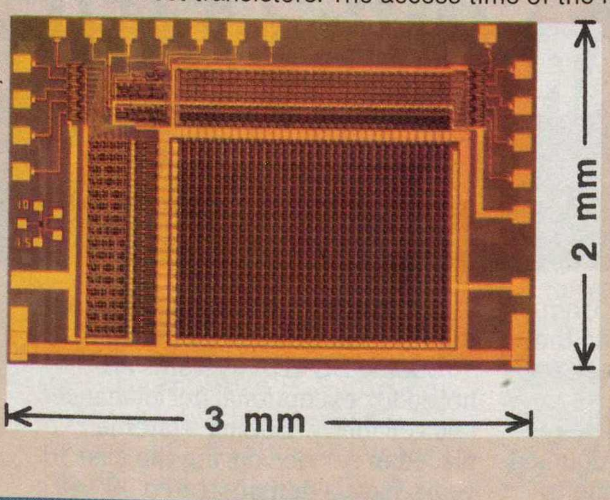
Nestled inside the bottom lobe of a capital letter B typed on a piece of paper is a tiny semiconductor laser diode made by Bell Laboratories of Murray Hill, N.J. This laser, known as a cleaved-coupled-cavity laser, is one example of a new family of single-frequency semiconductor lasers being developed in the United States, Japan, and Great Britain. As recounted in more detail in the article beginning on page 38, such single-frequency lasers, when used as light sources in fiber-optics communications systems, will allow information to be transmitted at unprecedented bit rates over distances longer than 100 kilometers between repeaters. In addition, high-power single-frequency lasers will allow high-speed information to be transmitted over local-area networks with enough signal strength to overcome losses at splices and connections. The promise of laser diodes is such that they are being heralded by some researchers as the fourth generation of fiber-optics communications components.


Bell Laboratories

If experimental gallium arsenide large-scale integrated circuits can be moved successfully from laboratory to market, they will offer computer and instrumentation manufacturers a more than tenfold increase in speed over current high-speed silicon-based logic, but with significantly lower power dissipation [see "Integrated circuits: the case for gallium arsenide," p. 30].

The 1-kilobit static random-access memory shown was developed in 1982 by researchers at Fujitsu Laboratories Ltd. in Kawasaki, Japan, and integrates 6852 field-effect transistors. The access time of the RAM is just under 4 nanoseconds and it has a power dissipation of 68 milliwatts. A differently designed 1-kb RAM developed by Nippon Telegraph and Telephone has a 2-ns access time and power dissipation of 459 mW. High-speed GaAs logic circuits such as multipliers and frequency dividers have also been developed.

Fujitsu Ltd.


ARTICLES

Advanced technology

Applications

Large Systems

Special report

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DEPARTMENTS

1884 · 1984
A CENTURY OF ELECTRICAL PROGRESS

THE COVER

In this screen from a new video game by Simutrek Corp. that will soon make its appearance in arcades, the background was computer-generated and stored on video disk (by Robert Abel & Associates) and the bees were generated in real time. Such 3-D images previously existed only in flight simulators.
See article on page 52.

Consumer electronics

Video games: the next wave

Interactive video-disk technology lends reality to arcade games, but purists believe the ultimate lies in real-time computer-generated graphics

Two new developments in arcade video games show promise of rousing the industry from a torpor that has gripped it for the last year. The first development is the third generation of real-time raster-based and vector-based games, offering three-dimensional solid graphics for the first time. The second is laser-disk–based games, which, while failing to give players real-time control and the freedom to move at will in the game, overwhelm them with graphics heretofore achieved only on movie screens.

A stir is needed in the industry because, after five years of phenomenal growth, the arcade business has nose-dived. Many one-time players appear tired of gulping dots in mazes and fighting two-dimensional alien characters. Some designers of video games say it is understandable that players, who have not seen a novel video game in a long time, are bored. But that does not mean the video-game fad is dead, the designers say.

In 1973, they note, electromechanical pinball machines were pushed aside to make room for Pong and other first-generation video ball-and-paddle games. In 1978, Space Invaders, with two-dimensional characters, heralded the second generation of video games. Now the third generation is leaving the research and development stage and has just begun to make its way into the arcades. It will revive the players' interest, claim designers.

"It's like the movie business," said Noah Anglin, president of Simutrek Corp. in Hayward, Calif. "Remember right before *Star Wars* came out, when everybody was crying that the movie business was dying, that video games killed the movie? All that was wrong was that they were all lousy movies. Well, for the last two years only lousy video games have been done."

A struggle among designers

But while the picture has brightened for video-game players, it is not yet in focus for game manufacturers. Which of the new design approaches will predominate? Third-generation raster- and vector-technology supporters are battling to keep video-disk–based designs from taking over. The disk designers are jockeying among themselves for position as different ways of exploiting the technique have emerged.

Tekla S. Perry Associate Editor

This year the first laser-disk game reached arcades—Dragon's Lair, by Starcom. It is admittedly crude—the Pong of the technology, said its creator, Rick Dyer—and critics complain that it robs the players of real-time control. But the Disney-like animation on its screen, replacing simple computer graphics, is drawing the quarters of crowds of players.

Other video laser-disk games are about to be shipped to arcades, each using the technology in different ways: Astron Belt, from Sega Electronics in Los Angeles, Calif., is based on film footage, and Cube Quest, from Simutrek, uses a disk that, the company says, contains $5 million worth of movie-quality computer images.

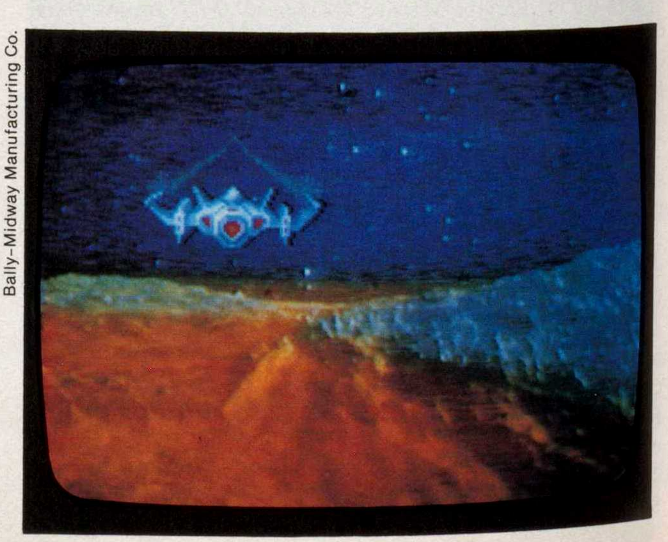
Video-disk players are available in two formats: CED (capacitance electronic disk) and laser disk. Until recently, only the laser form offered interactive options—the capability to seek and display any frame on the disk quickly. The RCA Corp. has introduced a random-access CED player, but so far only laser disks are being used in game design. The use of the laser video-disk player as an interactive medium has been limited. Equipment has been designed to allow the user to page through documents or to study the steps performed in repairing a machine, but not for moving freely.

Yet, using a standard industrial laser video-disk player, a Z80 microprocessor, and 64 kilobytes of read-only memory, designers have created a successful video-disk arcade game. It is a very simple use of video-disk technology—but it works.

The moving force behind the development of Dragon's Lair was Mr. Dyer, the founder of Advanced Microcomputer Systems, Pomona, Calif. He suggested that his company engineer the video-disk system, that Don Bluth Productions of

RDI Video Inc.

Bally–Midway Manufacturing Co.



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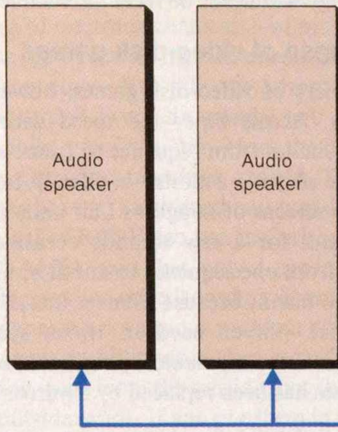
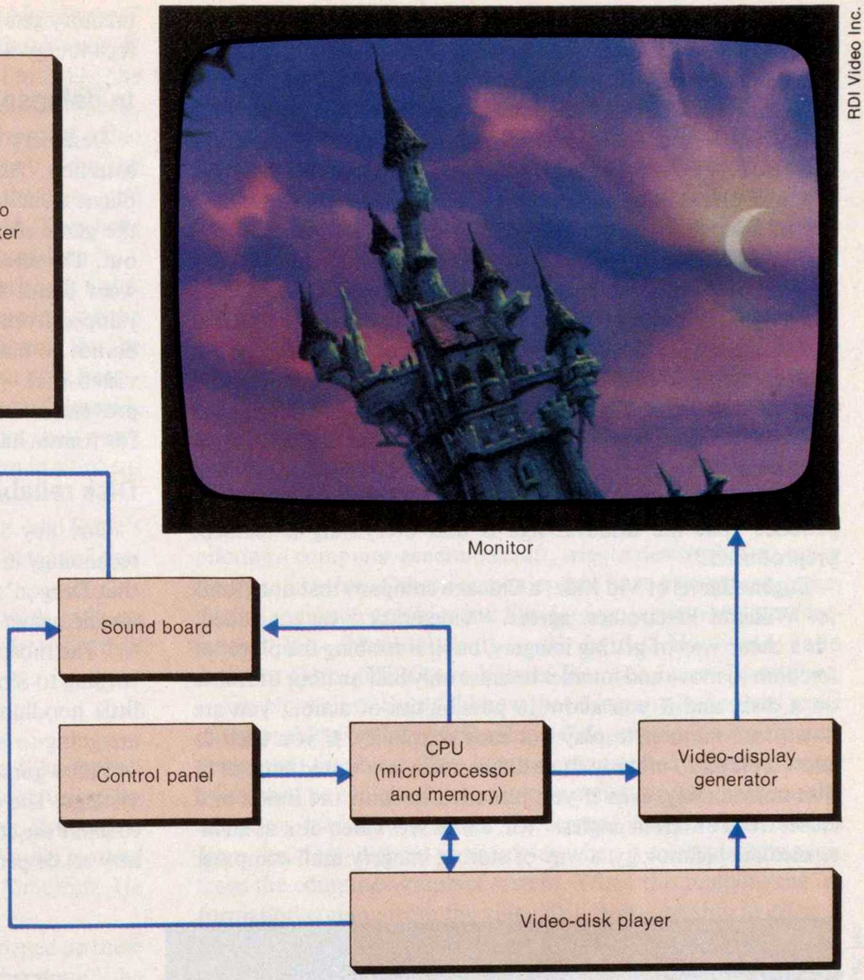


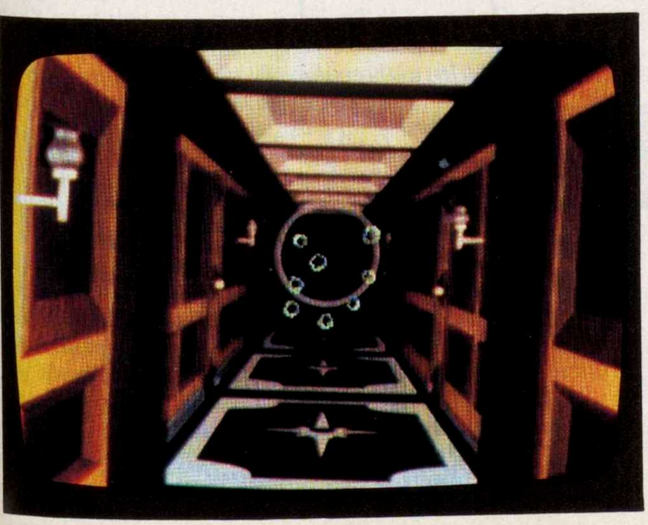


[2] In a video-disk game that also uses overlayed computer graphics, the player controls the game via the control panel. The player tells the CPU what frame number is being displayed on the monitor; the CPU in turn passes control information to the video-disk player, telling it what frame number to search for next. The video-display processor generates computer graphic images according to instructions from the CPU, synchronizes those images with the video-disk–created images, and displays them on the raster monitor. The sound board generates sound according to instructions from the CPU, takes the sound from the video-disk player, and passes both to stereo speakers.

Hollywood, Calif., an animation house, do the graphics for storage on the disk, and that Cinematronics, an arcade-game manufacturer in El Cajon, build the game. The joint venture blended into a company called Starcom, which is marketing the game from San Diego, Calif.

The most impressive characteristic of Dragon's Lair is its animation. Mr. Bluth, a former animator for Walt Disney Productions, and his team created a cartoon about the adventures of Dirk the Daring as he attempts to slay a dragon and rescue a princess. The players control a joystick and an action button: push the joystick the right way at the right movement and hit the action button at appropriate times, and the cartoon progresses; fail to make the right choice fast enough, and Dirk the Daring dies. The players do not control the action itself, but if they make all the right choices, in 16 minutes they will see Dirk slay the dragon and win the princess. Other companies are also planning to sell similarly animated adventures, including Stern Electronics, Elk Grove Village, Ill., with Cliff Hanger and Centuri Inc., Hialeah, Fla., with Badlands.

Simutrek Corp.



But is control of the sequence of action enough? Some game designers think not. They say the players must have real-time control of the game for it to be truly challenging. And only designers of computer-generated games, be they raster or vector format, can offer such freedom, they contend.

"Even with Pong, you had the feeling that you had infinite variety in your control," said David Sherman, an engineer at Atari Inc. in Milpitas, Calif., who is currently working with raster technology.

"Even that crude a computer game, because of variations on the way the ball bounces, couldn't be stored on video disk. With a video disk, the game is playing you; you're not playing the game. You are right or wrong, end of discussion," he added.

Other designers of computer-generated video games also agree that video-disk games are inherently limited: a video disk stores

◀ *[1] A wide range of images can be stored on video disks and integrated into a video game. The graphics in Starcom's Dragon's Lair (left) were created by animators. The images of Sega Electronics' Astron Belt (center) were assembled from Japanese movie footage. In Simutrek's Cube Quest (right), scenes were computer generated by Robert Abel Associates of Hollywood, Calif., and then transferred to a video disk.*

54 000 frames of information on one side and spins at 1800 revolutions per minute, providing only half an hour of imagery, and while technological developments could increase this time limit, video production costs are astronomical and incorporating more than 30 minutes of video in a game could price it out of the market. Frames are selected by redirecting the laser beams—that is a mechanical act, and limited also.

"In video disk you are in a finite medium," said Ed Rotberg, vice president for software development at Sente Technologies, a division of Pizza Time Theater Inc. of Sunnyvale, Calif. "There are only 30 minutes of video, there are only certain things that can happen. There are not infinite varieties of situations. With a total computer-controlled game, there is no such restriction, and the potential depth of the game is greater." Peter Langston, head of games development for Lucasfilm Ltd. of San Rafael, Calif., observed, "The obvious strength of video disk is that you can have very high-quality images—as high-quality as television can produce—but the disadvantage is that everything is canned, preproduced."

Eugene Jarvis of Vid Kidz, a Chicago company that does R&D for Williams Electronics, agrees. "Video disk," he concluded, "is a cheap way of getting imagery, but it is robbing the player of freedom to move and interact because only half an hour of film is on a disk, and if you allow 10 possibilities of action, you are down to 3 minutes to play out each possibility. If you tried to allow a player to move in three dimensions, you would run out of film immediately, even if you just tried to show the inside of a closet from different angles." Mr. Jarvis sees video disk as an intermediate technology, a way of storing imagery until computer memory gets cheaper than it is today. He believes that video-disk technology will never be truly interactive.

In defense of video-disk games

Designers of video-disk games, however, disagree with that assertion. Access time—the speed with which the video-disk player switches from sequence to frame sequence in response to the game player's actions—is already faster, Mr. Dyer pointed out. The screens of Dragon's Lair units shipped before October went blank for a few seconds occasionally when the action jumped from one sequence to another; units now being shipped do not go blank, because Pioneer Inc., the manufacturer of the video-disk player used in those systems, made an improvement—the mechanical arm that scanned the disk to search for frames has been replaced by a mirror that redirects the laser.

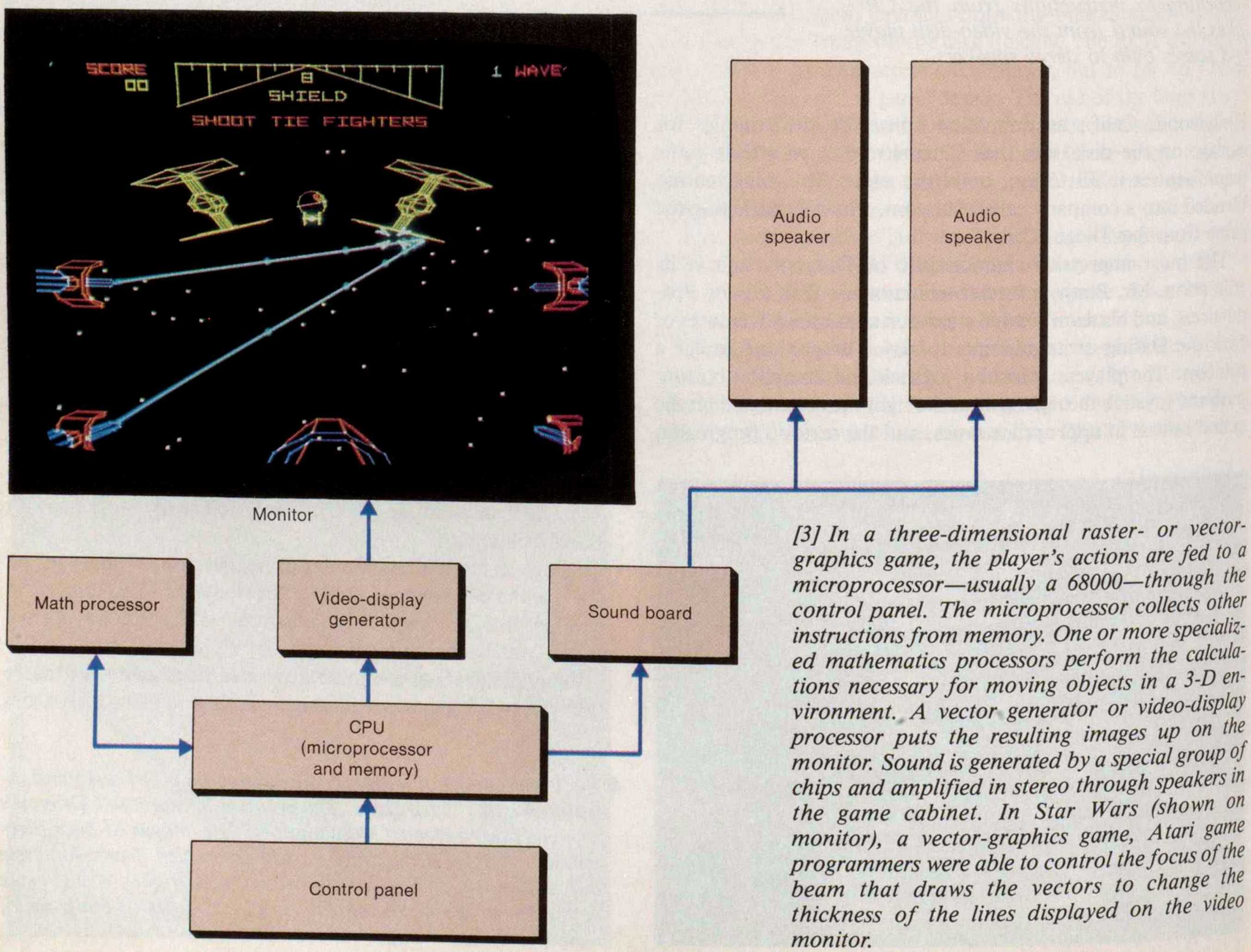
Disk reliability can be troublesome

One key issue being raised about the use of video-disk technology in video games is the question of reliability. "I threw that Dragon's Lair game out of my arcade the first week," one arcade owner said. "Every time a kid pounded on it, it broke."

"The most alien environment on earth is a game arcade," according to Simutrek's Mr. Anglin, "because who is there? These little hoodlums, that's who—these 12-to-16-year-old guys who are going to kick the holy hell out of your machine."

Video-game manufacturers have learned to protect their systems. The electronics inside are not endangered, but they had to make the controls rugged. But video-disk players have added a new set of problems.

Atari Inc.



[3] In a three-dimensional raster- or vector-graphics game, the player's actions are fed to a microprocessor—usually a 68000—through the control panel. The microprocessor collects other instructions from memory. One or more specialized mathematics processors perform the calculations necessary for moving objects in a 3-D environment. A vector generator or video-display processor puts the resulting images up on the monitor. Sound is generated by a special group of chips and amplified in stereo through speakers in the game cabinet. In Star Wars (shown on monitor), a vector-graphics game, Atari game programmers were able to control the focus of the beam that draws the vectors to change the thickness of the lines displayed on the video monitor.

"Laser disks are much more fragile than standard hardware," Mr. Rotberg said. "Part of the problem is the operator's fault. If you go back into the era of electromechanicals—of pinball—the operator knew that if he didn't service his machines once a week, they were going to break down. But with the advent of video games, what was there to do? Every six months you clean the contacts; if something fails, you fix it. You clean the glass, and that's the maintenance. Operators have been spoiled. They have to realize that laser disks have to be cleaned and tuned up."

Mr. Dyer, now president of RDI Video Inc. in Carlsbad, Calif. (though still owner of AMS), said that only 1 percent of the Dragon's Lair games shipped had experienced problems. But, he indicated, video-disk games have a serious problem with heat.

"They have to be in an air-conditioned environment," he said. "We have fans that bring in air from the outside, but they won't do any good if the air outside is hot. If you put them in a hot environment, they will break down all over the place."

One problem associated with heat is disk warping, said Sente's Mr. Rotberg. "When they shut that machine off, there is all that heat sitting there, and the disk will warp."

In Dragon's Lair that problem was addressed with an aluminum-backed disk that conducts the heat away from the disk and stops it from warping.

Economy approach being tried

Simutrek, however, will break all these reliability rules and set a few of its own with the system it is currently manufacturing. Instead of the sturdy $1500 industrial laser-disk player, Simutrek is basing its system on a $700 consumer model. Mr. Anglin worked on computer disk drives at IBM before joining Simutrek. He ripped apart a laser-disk player.

"Anybody well versed in disk technology who opened up these laser-disk players would do some of the things I've done," he said "because it is just common-sense engineering. For example, we designed a multiplane shock mount system for the disk player to sit on. You can kick the daylights out of my machine, and it has no effect on it."

Competitors, he said, "are mounting the player on drawer slides and bolting it to the cabinet, so every time the kid pounds on it, that's it. This is a very fragile instrument. I have it mounted the way HP mounts its instruments. The other guys are shipping their product without the laser disk in it; the player is installed by guys in the field. I don't want those animals handling my equipment."

Mr. Anglin is also using standard plastic instead of aluminum-backed disks, counting on a cooling system to prevent warping. "Pioneer keeps calling me and asking, 'Noah, are you sure you don't want that aluminum backing?' " he said. "I don't want it—they want several extra dollars for it and these plastic disks are tough enough. They say everyone else is using aluminum. I say great—that gives me a $7 price advantage."

Steven Ritchie, cofounder of King Video Design in Loomis, Calif., is not involved in video-disk-game development—yet. He plans to wait to learn from other companies' mistakes.

"I haven't thought about it much," he said, "but it seems simple enough to isolate the players from vibrations. Why not store the disk units separately, where the operator can maintain them and they are not subject to vibration, and run a cable to the game. They can be enclosed in a very friendly environment—even a box in the corner of the arcade."

Those who expect video-disk technology to survive in arcades for years to come are counting on help from computer graphics to make the games more interactive. By overlaying computer-generated graphics on video-disk backgrounds, designers can let the game player control a character as well as the sequence of action. To do this, designers must program a standard video game, storing graphics instructions in ROM, adding a video chip to transfer these instructions to images seen on the monitor, and installing a microprocessor to accept the players commands, coordinate the behavior of the object, and integrate the real-time and video-disk images. Though the game is still limited to one perspective—that of the photographer who filmed the background—the player can at least move around on the screen in real time.

Sega Enterprises, whose game will be distributed by Bally-Midway of Chicago, has taken this approach. The company's Astron Belt was the first video-disk game demonstrated, but it has yet to reach U.S. arcades though it is available in Japan and Europe. It has a space-battle theme, using 30 percent stock film clips from old Japanese movies and 70 percent custom-generated footage to produce an interactive background of enemy spacecraft and surface installations that the player, piloting a computer-generated craft, tries to destroy before being hit by return fire. Other companies that have announced games mixing computer graphics and film footage include Mylstar Electronics Inc., Northlake, Ill., with M.A.C.H. 3 and Taito America Corp., Elk Grove Village, Ill., with Laser Grand Prix.

Mr. Norwalt of Sega told how that company had solved some of the problems of integrating video-disk graphics and computer-generated graphics. The computer-generated graphics were overlayed, he explained, by imitating a matting technique: as the television scan moves across the screen, it is fed information from the video disk up to the point when it selects information from the computer-graphics system. When this happens the information coming from the video disk stops, making in effect a black mask into which the computer-graphics image is dropped.

In Astron Belt the computer-generated plane can fire at and blow up images on the video disk—and those images appear to fire back. Dr. Norwalt explained that the Zilog Z80 microprocessor in the system reads the number of the frame being displayed by the video disk. Each frame is coded with a hit spot, which is stored in ROM. The microprocessor checks these hit spots with shots fired, and if the coordinates correspond, it instructs the video-disk player to display an explosion sequence. In some sections of the game, the player must navigate between walls. Here the walls are coded, and collisions are detected.

Another approach to a video-disk-based game is being taken by Simutrek, which hopes to "blow the industry away" with its efforts, according to the company's president, Mr. Anglin. He said several of Simutrek's 20 engineers have been working 100 hours a week for a solid year to develop Cube Quest.

"This is an ego-driven business," Mr. Anglin said. "My guys aren't in it for the money; we want to be recognized as the best."

Simutrek has taken a unique approach. Instead of designing its system around off-the-shelf industrial players, Simutrek is ripping the insides out of cheap consumer video-disk players and replacing them with a system that has been submitted for patenting. "We are using our own microprocessor controller, adding a circuit-board module inside the disk player, recabling it, doing a few tricks with the carriage-rail system, and ending up with a reliable system that basically runs forever," Mr. Anglin reported.

Mr. Anglin offered Simutrek stock to Robert Abel & Associates of Hollywood, Calif., one of the top computer-graphics companies in the United States, to design graphics to be stored on a video disk and used to enhance the game. When Cube Quest is released, it will contain half an hour of computer-graphics imagery that would cost $5 million to buy (a 90-second Corvette commercial recently completed by Abel sold for half a million dollars), according to Mr. Anglin. Other companies that have developed laser-disk games based on computer graphics include FunaiESP, Las Vegas, Nev., with InterStellar and Williams Electronics Inc., Chicago, Ill., with Star Rider. Star Rider is unique in that it uses a line buffer—the entire screen is not visible on the monitor at the same time. This allows limited right and left scrolling and gives the player a sense of controlling perspective.

Simutrek's game selects images from the disk randomly. There is no blanking, Mr. Anglin says, "because through my ability to control the disk player, I do things in milliseconds, not seconds."

Another approach to the seek-time that is expected to be attempted by some companies is installing two disk players in the game, running in parallel. This approach, however, is risky competitively, as it almost doubles the hardware cost.

Computer games: the third generation

In addition to exploiting the new technology, Simutrek is also one of the companies responsible for bringing third-generation computer games to the arcades. This two-pronged approach is possible because it chose a consumer rather than industrial disk player and is saving at least $700 a unit, Simutrek says. It can afford to invest heavily in electronics technology and remain competitive on a cost basis with other arcade machines. In fact, the movement of video-disk technology into video games may be paving the way for advances in traditional computer video-game graphics by raising the amount of money arcade operators expect to spend for a video game. Up to now, the hardware that went into a coin-operated video game, excluding monitor and cabinet, was a few hundred dollars; the game retailed for $2000, and arcade operators charged 25 cents to play. The introduction of video-disk technology raises the minimum hardware cost to $1500, the retail price to $4000, and the playing cost to 50 cents.

Surrounding the players with sound

Designers of third-generation video games are paying a lot of attention to how they sound.

Most previous games, according to Noah Anglin, president of Simutrek Inc. in Hayward, Calif., used a Texas Instruments Inc. sound chip or something similar to generate sounds. "You've got four channels at the most; they create little wimpy explosions and little wimpy sounds," he said. In Simutrek's first game, Cube Quest, which contains a video disk but has a computer game system that operates independently, sounds will be created in 16-channel stereo by a microcoded 2901 bit-slice microprocessor.

"You usually can't get sound out of a 2901," Mr. Anglin said, "but I can create an entire orchestra, with one channel a kettle drum, one a violin, one a flute. The sound system is so good, with custom amplifiers and a custom baffle system, that the cheap $3 speakers we are using in the cabinet could put the Bose speaker system on GM cars to shame for a twentieth of the money. The engineers here had expensive speakers in the back room on their stereo system; they unhooked them and played their stereo through the game cabinet, and it played better. Hopefully we can patent this."

At Atari Inc. in Milpitas, Calif., Greg Rivera, a senior programmer, said designers are also using digitally recreated stereo. He explained that comb filters, used to destroy phase information on cassette tape players, were too expensive for use in video games until recently, when an analog delay chip was designed that could implement a comb filter.

"Your ears use the phase information to decide where the sound is coming from," Mr. Rivera noted. "If there is no phase information, your ears give up and say, 'I have no clues at all, so it must be all around me.' This helps the person believe that he is inside the game." —*T.S.P.*

As the cost of electronics has continued to come down, arcade operators are getting a lot for their money: 16-bit microprocessors, particularly the Motorola Inc. MC68000, are becoming the standard of the video-arcade-game industry (the 6502 was the standard of the previous generation), and specialized math processors, particularly the Advanced Micro Devices' 2901, are now widely used.

"The 2901 is a lot more painful to program than the 68000," Peter Langston, head of games development for Lucasfilm, said, "but it is one of the ways you can get faster than a 68000, and some things just have to get faster." And because of advances in large-scale-integrated design that have reduced the cost and the turnaround time of manufacturing custom chips—from $500 000 and eight months a few years ago to $50 000 and 14 weeks today—most third-generation games will contain several custom chips, both to reduce manufacturing costs and protect the secrecy of the designs.

Companies are more flexible now about the hardware designers are allowed to put into games. "Before, a person with a good game idea was told, 'Here's a 6502, and anything it can do, you can use, and anything else you can forget,' " Mr. Langston said. "Now game ideas can creep outside the bounds of any one processor. In the last few years we passed the peak of prosperity, and companies that thought they were sitting pretty and could write the rules are now willing to listen to other possibilities."

What can be done with the extra money and the new technology? The answer appears to be real-time, three-dimensional graphics. Simutrek's machine, Mr. Anglin said, can do true 3-D perspective, with hidden-line and hidden-surface removal—the capability to faithfully render opaque objects—though Simutrek's first game, video-disk-based, will not show off the full power of the system.

"When we started designing this game last October," Mr. Anglin said, "I wasn't sure how much power I'd have. But in our next game we'll be able to do all that a Link simulator [made by the Singer Co., Stamford, Conn.] with 30 000 ICs can do."

The Simutrek game uses a 68000 as system manager, with instructions programmed in bits and pieces of assembly language, variations of Forth, and C stored in 16 64-kilobyte ROM chips. The calculations to do 3-D transformations through z-depth buffering are done by seven 2901 microprocessors instructed in microcode. These calculations allow the position of every object to be monitored along three axes—x, y, and z. Therefore, the system can easily figure which objects are "closer" to the viewer and pass in front of other objects.

"The microcode is the most important element," Mr. Anglin said. "It lets you take a minimum amount of hardware and do things you usually need a lot of hardware for."

He said other companies have discussed obtaining licenses for Simutrek's hardware for use in computer-aided-design and -manufacturing systems.

While simulator technology traditionally uses calculations of depth on a z axis to create a 3-D environment, z-depth buffering is not the only way designers are creating 3-D for the new generation of coin-operated games. At Atari, Mr. Sherman is the hardware engineer on a team that is developing a 3-D video game. He explained his approach.

"My new game puts a 3-D image on a raster screen. It can do sunshading, hidden-surface removal, and object-to-object clipping by filling up a bit map very quickly."

The objects are sorted by z-depth, Mr. Sherman explained, and as the bit map fills up, the farthest objects are displayed first, with the closer objects writing over them. "The unusual thing is being able to fill up a bit map that quickly," he said. "It could fill faster than a scan. The thing that fills the bit map is a state machine [a circuit] that cycles through 32 states, and, by being judicious about how I coded those states, the output ended up being the actual filling operation of the bit map. It was a lot like putting a supercharger on a Volkswagen—there are a lot of little tweaks, a gate here and there. It's not real structured."

The end points of the 3-D objects, polygon shading, and hidden surface removal are calculated by a 2901 processor, "basically all the graphic manipulations for the video processor," Mr. Sherman said. "The 2901 has 1 K by 52 bits of microcode, which I'm sorry to say I wrote—it really needed 2 K to fit in, so I don't know how I managed."

Mr. Sherman's game uses a standard monitor with a resolution of 256 pixels by 240 scan lines, but, he said, "I faked it up to look like 512 by 240: I can delay half a pixel clock to turn on a pixel and display the edge of an object, so some of the diagonal lines look better. It's not really 512 resolution, because I can't turn on the left half of a pixel."

The hardware, in addition to the state machine already described, uses a Motorola 6809 microprocessor, 14 64-kilobyte RAM chips, 90 kilobytes of ROM, a 2901 math processor, and a custom video chip that incorporates the state machine. Mr. Sherman says his system basically does what large-system simulator technology does, but with less resolution and a few tradeoffs. He cannot calculate object penetration, so when objects try to intersect, they blow up. "On a real graphics machine you'd have to calculate that, but this is just a game," he noted.

"I'm not doing antialiasing, so objects alias in and out," he pointed out. (Because pixels are lined up on the vertical and horizontal axes of a television screen, diagonal lines, which turn on the entire pixels, end up looking jagged. Antialiasing techniques smooth out such lines.) "That's acceptable for a game, because there is so much going on. People want to know there is an object there, but they don't see the detail in it until it gets to a certain size. I have an advantage. Someone at a graphics company has to worry about every problem in the universe, while I don't have to worry about the oddball exception—I just make it a part of the game, so the guy dies if he tries to do that."

On an acre of land tucked among farms and duck ponds near Sacramento, Calif., a small group of engineers, headed by two former pinball-game designers, Steven Ritchie and Douglas Hughes, have spent a year and a half attacking the problem of 3-D interactive video—from a different angle. Instead of using a lot of tricks, they are taking a brute-force approach. The name of the company is King Video Design.

The first game to come out of this company will use a 68000 microprocessor, 14 custom LSI chips, 64 kilobytes of RAM, and 780 kilobytes of ROM (a typical second-generation video game used perhaps 80 kilobytes of ROM, and the game with the most detailed graphics of that generation, Zaxxon, had 200 kilobytes of ROM). Through custom chips, the King Video game system transfers images stored in ROM directly to the screen, bypassing the standard process of ROM to RAM and RAM to display transfer. So much memory allows 3-D rotations to be prestored instead of calculated such as 140 views of one ship.

Because of the massive amounts of information that must be programmed into the game to present it fully in three dimensions, King Video spent most of its year and a half of R&D on a development system. That system, which digitizes objects viewed by a video camera, was completed in July, and then real work began on the first game. The next game, the company said, will take better advantage of the newly developed hardware.

"We have a tremendous amount of data moving on the screen—the objects, the explosions, all moving," Mr. Ritchie

Coming: video-disk games for the home

Because homes are potentially a much bigger market than arcades, the developers of arcade video-disk games have their long-range sights on the private consumer.

"Dragon's Lair wasn't my main goal," said Rick Dyer, who assembled a joint venture, Starcom, that put the first video-disk game in arcades. "It's just another arcade game, but it was necessary as a vehicle to educate the public. The home interactive video system I am developing is the real goal."

Ed Rotberg, of Sente Technologies in Sunnyvale, Calif., agreed. "Video-disk games are more suited to the home market," he said. "You don't want to do a completely non-real-time game in an arcade, but you can get away with it in the home—look at the popularity of computer adventure games. Video disk is the perfect tool for an adventure game."

A major problem keeping video-disk games out of the home market right now is the cost of disk players. At $700 each, they are hardly toys. And the public does need education, said Francis Roefaro, head of communications for Vidmax in New York, manufacturer of the MysteryDisk series—the first home video-disk games.

"One salesman was opening a disk player to show it to a woman in a store," Mr. Roefaro said, "and she asked if she should stand back so the laser wouldn't zap her."

The MysteryDisk games are played on standard laser-disk players without a special interface. Different information is recorded on different sound tracks and at various points in the game the player is asked to select different chapters and frames. The selections affect the progression of the mystery. The first MysteryDisk game—Murder, Anyone—had one murder and different story lines. The second MysteryDisk, Many Roads to Murder, has three murders and 16 different stories, thanks to the development of a computer authoring system that allowed the scriptwriter to keep track simultaneously of the different branches in the selection tree.

The MysteryDisk games contain approximately 15 minutes of action video. The rest of the disk is filled with still frames that provide information that can be paged through. It demonstrates an innovative use of the home video-disk player for limited interaction—but this is about all the interaction the current video-disk players can provide. A technological advance is needed to bring an interactive video-disk game system into the home.

That step will be taken and demonstrated at the Summer Consumer Electronics Show next June, predicted Peter Langston, head of game design for Lucasfilm Ltd., San Rafael, Calif. "Video disks can be made to really catch on in the home market," he said. "There is an opportunity to do a real good job in terms of organic design here, to build something that is very inexpensive to construct and very sturdy, to essentially spend a great deal of time and money on design, because it is going to be amortized over millions of units a year."

Coleco Industries Inc., of West Hartford, Conn., has signed an agreement with Starcom, giving Coleco rights to home versions of Dragon's Lair. Coleco has indicated that in 1984 it will manufacture such a product and claims that it will "have significant impact on the home electronics industry."

Another home video-disk game is being developed by Mr. Dyer through a new company he has formed, RDI Video Systems of Carlsbad, Calif. "It's going to be the Lewis and Clark expedition," he said. "You are going to ride in the canoe with Lewis and Clark, and you will make the decision whether or not you want to explore the Indian camp. When the Indians attack you, you can decide whether you want to fight, flee, or stand your ground. You will experience history instead of reading about it. I think it is going to have a revolutionary impact on education." —*T.S.P.*

said. "We thought we'd run the system up against the wall, but it turns out we're only using 50 to 60 percent of the real time of the processor, so we're in fat city; we can go ahead and do a lot more stuff in our next game."

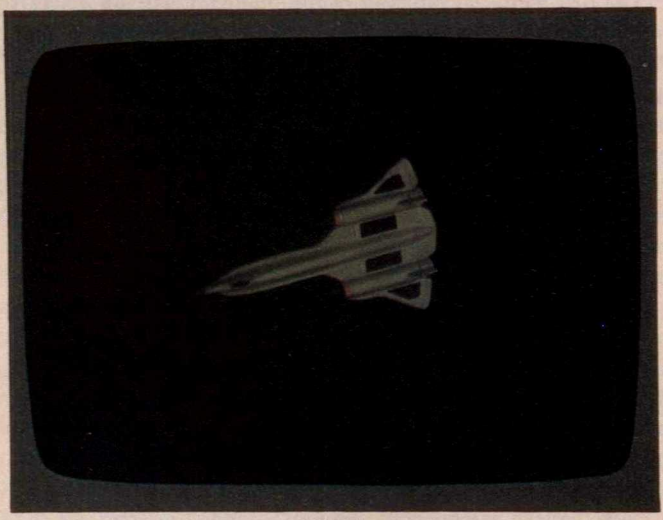
Vector graphics: another contender?

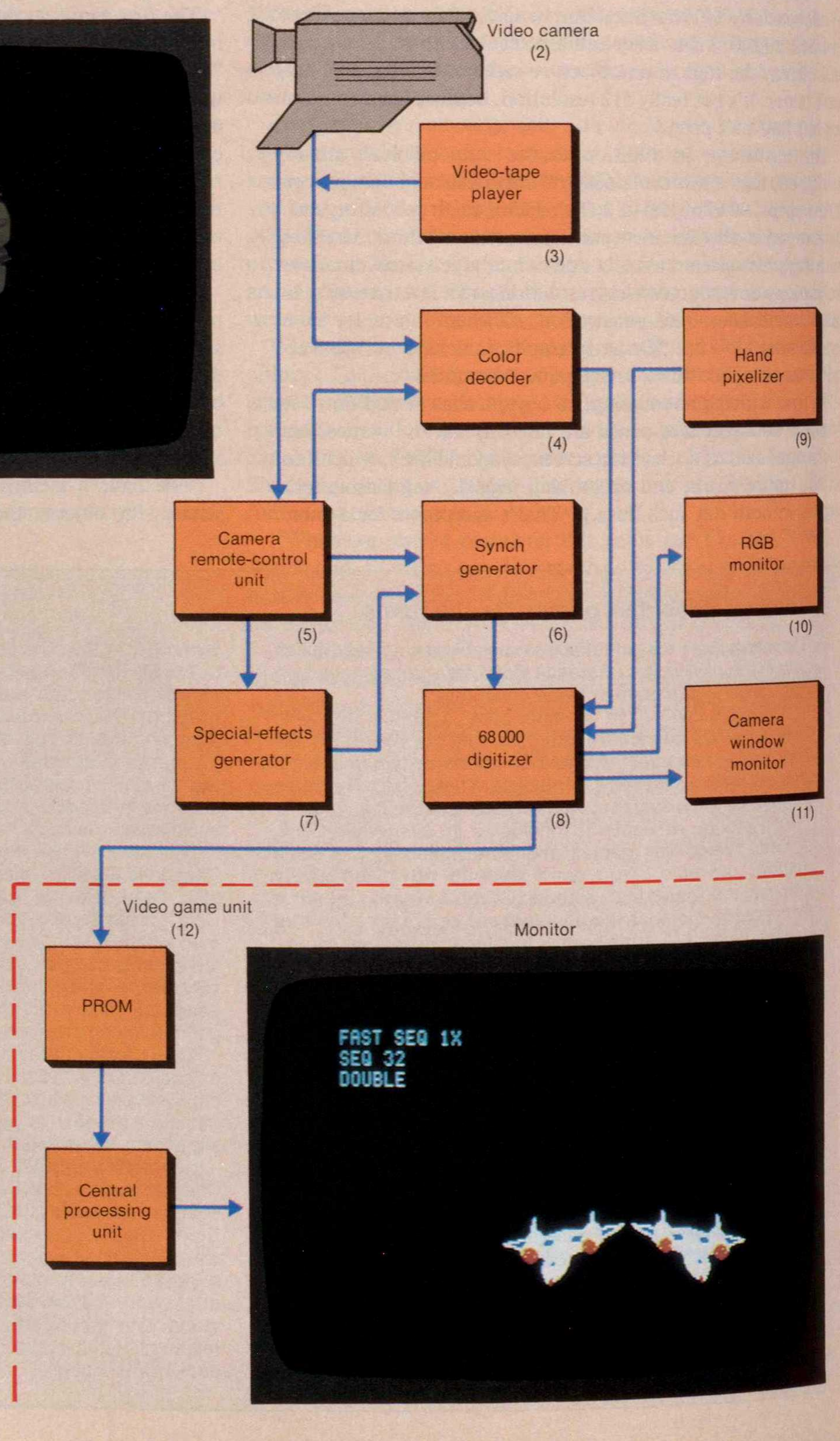
Another computer-graphics technology is also moving into a new generation. That technology is based on vector graphics. In the second generation of video games, 3-D effects were obtained through the use of a vector generator, first used in a video game in 1979. It could be manufactured for $150 when the cheapest commercial vector generators available cost $2000 to $3000. In succeeding second-generation video games, engineers improved on the vector system, adding color vectors and freer and freer movement in a 3-D environment.

Vector games are distinct in appearance from raster games; the display is not created by scan lines, as in a standard television image, but rather by lines drawn from point to point, usually on an

Development tools: keeping up with the new generation

King Video Design (photos)





In the King Kamera System, an object is placed on the animator (1), which remotely moves the object increments along x, y, and z axes as it is viewed by the video camera (2). Or the source can be prerecorded on a video-tape machine (3). The color decoder (4) strips the video signal down to its RGB components. In parallel, the signal is fed into a camera's remote-control unit (5), which strips off the synchronizing segment of the signal and feeds it into a separate sync generator (6). The output of this camera unit also goes into a special-effects generator (7). Inside the digitizer (8), which is made up of components including three MC68000 microprocessors and 100 128-kilobit RAM chips, the RGB image is digitized and realigned with the video-sync signal. The operator can control the range of colors used to alter the appearance of an object and can manipulate the object with the special-effects generator. Or the operator can "paint over" specific parts of the object, or create a new drawing, by using the hand pixelizer (9). Through the RGB monitor (10), the operator sees the object as the camera sees it, but in game resolution. Through the camera-window monitor (11), he sees the picture as the digitizer sees it, framed, and with alterations put in through the pixelizer or special-effects generator. When the operator is satisfied with the image, he sends it directly into the game, where it is stored in PROM (12).

x-y plane. This eliminates the problem of "jaggies"—stairstepping in lines drawn on the diagonal. Objects with clear details can be drawn, and 3-D geometry of points and lines can be easily handled because of the speed with which lines are drawn. However, vector generators do not easily fill areas with color, so objects are usually wire-frame—that is, outline—drawings.

Will vector be a contender in the third generation of games? No, said Mr. Anglin of Simutrek. "When I was at Atari," he explained, "we designed the vector system so we could do 3-D objects—we couldn't do that in raster. Now we can. Our dream was that someday we were going to be able to do hidden-line removal—vector hasn't gotten there yet. Then we said someday we'll be able to do x-y so fast we can do solid objects in three dimensions. Well, we're doing that right now, in raster."

On the other hand, Atari has just released a vector game, Star Wars, that goes far beyond previous vector games.

"The display on Star Wars is twice as fast as the previous vector displays," said Greg Rivera, senior programmer on the project, "and it has twice as fine a resolution. Right now, using x-y lines, we can put up enough lines to simulate half of a raster display," he said.

Atari had designs on the drawing boards that could again double the speed and resolution of vector generation. "Then we will be up to a full raster simulation using x-y graphics and will get the advantage of both technologies—more solid objects, fine detail, and crisp lines," he observed.

In Star Wars, engineers made a step toward simulating solid objects by allowing programmers to specify line width. The hardware changes the focus of the beam accordingly by a proprietary method that Mr. Rivera said "we stumbled on after doing a lot of experiments." By drawing fat lines to fill an area, not so many lines need be drawn.

Vectors may lose ground in the arcade-competition battle, however, if hybrid technologies become the norm—the output of video disks is a raster display, which can, with reasonable effort, be merged with raster computer-generated graphics. The task of merging a vector display with video-disk output would be, to quote one engineer, horrendous, because the video-disk output, which is in evenly spaced horizontal lines, would have to be converted into x-y points and lines connecting those points, or the x-y lines that can go in any direction on a vector display would have to be converted into horizontal lines.

The fourth generation: better monitors

The next development that will advance video-game technology, designers agree, will be in monitor technology with resolution increasing and cost decreasing. High-resolution monitors are too expensive for use in video games, they say, but the popularity of the personal computer will drive the cost of the monitor down, and 512 by 512 pixels will become the norm instead of today's 256 by 256. This will make a tremendous difference in graphics, designers claim.

To make this leap in resolution, however, memory and processor technology must also advance—doubling the resolution means four times as much memory and processing power are needed, because there are four times as many pixels that must be updated. And once monitor costs come down, why stop at one monitor—why not three or four to surround the player of a game? With shrinking costs of monitors, memory, and microprocessors, as well as advances in custom VLSI circuits, the sky is the limit.

"In five years the gap between what games can do and what the multimillion-dollar Link and Evans and Sutherland simulators can do will shrink to nothing," said Atari's Mr. Sherman. "We'll have a cheap pasteboard cockpit, someone will climb in, and he'll be flying a jet airplane."

For further reading

For an explanation of the history and programming of video games, see "Video games: the electronic big bang," *IEEE Spectrum*, December 1982, pp. 20–33, and "Design case history: the Atari Video Computer System," *IEEE Spectrum*, March 1983, pp. 45–51. ◆

The 16-bit microprocessor that is becoming the norm for video games can address much more memory than the 8-bit types formerly used, and increased memory can greatly improve the quality of game play and graphics. Yet more memory is not by itself all gravy for games designers. It means more programming—filling 800 kilobytes instead of 80.

"At first you look at this memory and say, 'Ah, I've just been put into a bigger room,' " said Eugene Jarvis of Vid Kidz Inc. in Chicago. "But then you realize that you've got to fill up that room, so you're in for a whole lot more work."

The development time for video games has usually been more than a year, and it is already hard to predict consumers' response to a game so far in advance. Clearly letting individual programmers work 10 times longer on a game will not ease this marketing problem. Some companies are assigning more programmers to projects, but splitting a game into too many parts has risks, too. The game may lose its "soul"—the personal creativity of the designer. The solution appears to be to increase the productivity of programmers by improving the tools they use.

Games are written in assembly language, because it is fast, and the images on the video display must change in real time in response to the player's actions. But a higher-level language would speed the development time. Companies like Atari are said to be looking into this possibility. The high-level instructions would probably be eliminated in the production models of the game, but they would allow designers to try out the game play—perhaps simulated on a minicomputer—before committing themselves to the time-consuming task of writing assembly language.

"That follows the credo of fail fast," said Peter Langston, head of game development for Lucasfilm Ltd. in San Rafael, Calif. "If the idea is bad, you want to find out sooner rather than later."

One of the first graphics tools of the third generation of video games is coming out of a small workshop in Loomis, Calif. Douglas Hughes and Steven Ritchie, partners in King Video Design, have developed a "digitizing system with pixelizing features"—meaning it can work from photographically captured images or from drawings done by an artist directly on the system, or combinations of both.

The unique feature of this King Kamera System is its capability to digitize "live." Previous digitizers worked from still black and white photographs shot separately for the red, green, and blue portions of the image. The King system is hooked to a video camera. Point the camera at an object once and press a button, and the image is stored in full color directly in programmable read-only memory, where it becomes a part of the game [see figure]. The system is being used to develop games for King Video, and it saves considerable time, according to Mr. Ritchie.

"I did a set of images for one spaceship before the system was running, and it took me six weeks," he said. "Now I can do a set of images for one ship in a night, easily, and make it incredibly more accurate."

At one point Mr. Ritchie decided to create an image of an asteroid. He borrowed a piece of pumice from his parrot's cage, where it had been serving as a beak sharpener, and placed it in front of his video camera. In a matter of minutes a three-dimensional asteroid, with detailed color and shading, was part of his game. —*T.S.P.*